HYDROGEOLOGIC RECONNAISSANCE OF THE SWOPE OIL SUPERFUND SITE AND VICINITY, CAMDEN AND BURLINGTON COUNTIES, NEW JERSEY

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Data presented in this report are in inch-pound units. To convert inch-pound units to metric (International System) units, use the following factors:

Multiply inch-pound unit	By	To obtain metric unit
inch (in.)	25.4	millimeter (mm)
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
square mile (mi^2)	2.590	square kilometer (km^2)
gallon per minute (gal/min)	0.06308	liter per second (L/s)
gallon per minute per foot [(gal/min)/ft]	0.2070	liter per second per meter [(L/s)/m]

Temperature Conversion

Temperature in degrees Celsius (°C) is converted to degrees Fahrenheit (°F) by the equation: $°F = (9/5)°C + 32$.

Sea level: In this report, "sea level" refers to the National Geodetic Vertical Datum of 1929 (NGVD of 1929)--a geodetic datum derived from a general adjustment of the first-order level nets of both the United States and Canada, formerly called "Sea Level Datum of 1929."

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By Gary J. Barton and Martha Krebs

ABSTRACT

From 1965-79, a chemical reclamation facility, now known as the Swope Oil Superfund site, sold and processed a variety of chemical compounds. Operation of the facility resulted in contamination of ground water beneath the 1.9-acre site. During 1984, the maximum concentrations of chromium and lead in ground water were 64 and 90 μg/L (micrograms per liter), respectively; the maximum concentration of total purgeable organic compounds (POCs) was 108 μg/L; and the maximum concentration of total base/neutral- and acid-extractable organic compounds was 116 μg/L. Although the off-site migration of these compounds has not been studied, a public-supply well 300 feet from the site is contaminated, and a public-supply well 1,400 feet from the site may be threatened.

The study area is adjacent to the tidally influenced Delaware River and is situated in the New Jersey part of the Atlantic Coastal Plain physiographic province. This province consists of a wedge of unconsolidated sediment which thickens and dips toward the Atlantic Ocean.

The study area is underlain by alluvial deposits, the Cretaceous Merchantville-Woodbury confining unit, and the Potomac-Raritan-Magothy aquifer system. These deposits, which are composed of gravel, sand, silt, and clay, crop out in the study area and are underlain by bedrock. These hydrogeologic units comprise the water-table aquifer, the confining units, and the confined aquifer found throughout the study area.

The Potomac-Raritan-Magothy aquifer system is incised by the Delaware River and is hydraulically connected to it. Regional estimates of hydraulic conductivities of aquifers and confining units in Cretaceous rocks are 130 to 350 ft/d (feet per day), and approximately 2.0×10^{-2} ft/d, respectively. The average yield of wells 6 inches or larger in the confined aquifer is approximately 1190 gallons per minute; specific capacity ranges from 17 to 80 gallons per minute per foot of drawdown.

The surface of the water table beneath the Swope Oil Superfund site is approximately 17 feet below sea level. Ground-water levels throughout the study area are believed to be below the stage of the Delaware River, causing induced recharge to the Potomac-Raritan-Magothy aquifer system from the river. Precipitation is the principal source of recharge to the water-table aquifer. Induced recharge into aquifers of the Potomac-Raritan-Magothy aquifer system from the Delaware River and downward leakage of water through confining units toward pumping centers in Camden County are the principal sources of recharge to the confined aquifer.

Five public-supply well fields are located in the study area, primarily adjacent to the Delaware River. During 1983 public-supply wells pumped approximately 25 million gallons per day of water, which accounts for

approximately 30 percent of all ground-water withdrawals by public-supply wells in Camden County. Four waste-disposal sites with observation-well networks are also located in the study area.

The water-table and confined aquifers are contaminated in several locations in the study area. The concentration of metals and purgeable organic compounds exceeds U.S. Environmental Protection Agency and New Jersey Department of Environmental Protection maximum contaminant level for drinking-water in more than 20 wells in the study area. Based on limited data, the maximum concentration of total POCs in water from public-supply wells is approximately 300 µg/L and at waste-disposal sites is 35,140 µg/L.

Construction details of 98 wells and 16 test borings are presented. Drillers', geologists', and geophysical logs made in 68 wells and 12 test borings are included. Ground-water levels measured during three water-level measurement programs from 1984-86, slug-test data, and ground-water withdrawals from 1956 to 1987 are listed. Results of more than 180 chemical analyses of ground-water samples collected during 1980-87 from 53 wells are given. Physical properties and chemical constituents including common ions, trace metals, purgeable organic compounds, and base/neutral- and acid-extractable organic compounds are reported.

INTRODUCTION

The study area includes the Swope Oil Superfund site[1] and adjacent areas in northern Camden and western Burlington Counties, New Jersey (fig. 1). From 1965 to 1979, a chemical reclamation facility was operated on a 1.9-acre site in Pennsauken Township, Camden County. This site is underlain by the Potomac-Raritan-Magothy aquifer system, the most heavily pumped source of water in the New Jersey Coastal Plain and the only source of drinking water in the area. Operations at the site contaminated the ground water with synthetic organic compounds and trace metals (NUS Corporation, 1985). Although off-site migration of these compounds has not been studied, a public-supply well 300 feet from the site is contaminated, and a public-supply well 1,400 feet from the site may be threatened.

The Region II Administrator of the U.S. Environmental Protection Agency (USEPA) signed a Record of Decision in 1985 recommending that a supplemental Remedial Investigation/Feasibility Study (RI/FS) be undertaken to evaluate the extent of ground-water contamination at this site (Geraghty and Miller, Inc., 1987). The USEPA subsequently requested that the U.S. Geological Survey provide technical assistance in evaluating the impact of the site, now called the Swope Oil Superfund site, on the local ground-water quality.

Purpose and Scope

This report provides a generalized description of the hydrogeologic framework, information on waste-disposal sites, and data on wells and test borings in the Swope Oil study area. These data were compiled from U.S. Geological Survey files and reports, New Jersey Department of Environmental

[1] The use of industry or firm names in this report is for location purposes only, does not impute responsibility for any present or potential effects on the natural resources.

Protection (NJDEP) files, and consultants' reports. Data collected prior to the initial 1985 RI/FS at the Swope Oil Superfund site are presented for historical perspective.

Also in this report are hydrogeologic sections and maps of the top of the bedrock surface and the potentiometric surface of the Potomac-Raritan-Magothy aquifer system. Locations of public-supply well fields, waste-disposal sites, and wells and test borings in the study area are shown on maps. Tables include well-construction details, specific capacities of wells, ground-water levels, slug-test data, ground-water withdrawals, and results of analyses for physical properties and common ions, trace metals, purgeable organic compounds, and base/neutral- and acid-extractable compounds in water from wells. Appendixes include copies of drillers', geologists', and geophysical logs for wells and test borings.

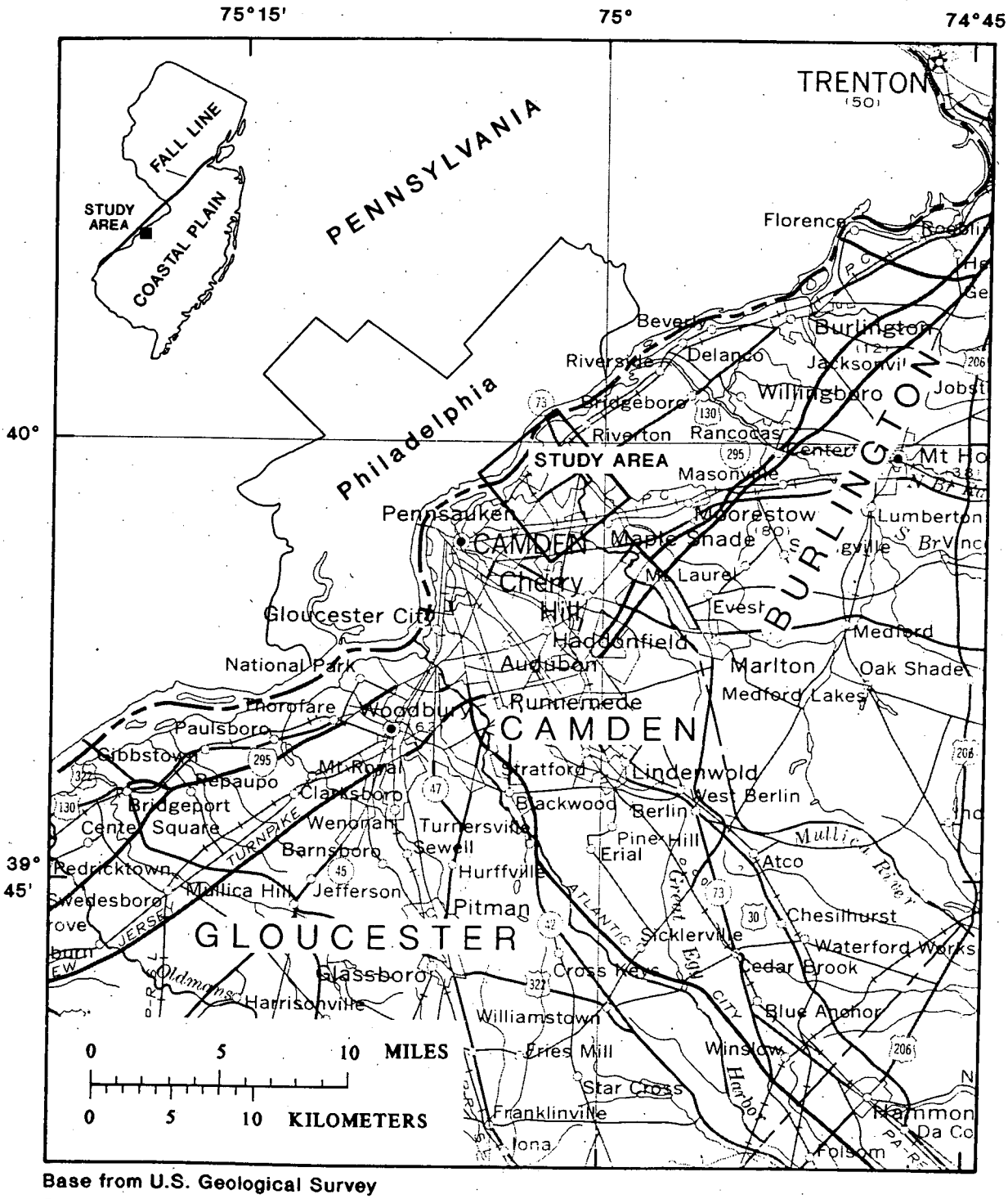
Previous and Ongoing Investigations

Previous and ongoing investigations adjacent to or including the Swope Oil study area focused on defining the regional hydrogeologic units, assessing regional ground-water resources, simulating regional ground-water flow in the Potomac-Raritan-Magothy aquifer system, and assessing waste disposal sites.

Gill and Farlekas (1976) developed geohydrologic maps of the Potomac-Raritan-Magothy aquifer system in the New Jersey Coastal Plain. Farlekas and others (1976) provided information on the ground-water hydrology of Camden County. They mapped the hydrogeologic units and addressed the availability and quality of ground water based chiefly on analysis and interpretation of ground-water levels, aquifer tests, water-use data, and water-quality data. Owens and Minard (1979) presented a detailed reconnaissance of upper Cenozoic sediments in the Delaware River Valley and the Northern Delmarva Peninsula, New Jersey, Pennsylvania, Delaware, and Maryland.

Vowinkel and Foster (1981) appraised and described the ground-water system, computed approximate hydrologic budgets, and summarized the effects of ground-water withdrawals on the natural hydrologic system of the Coastal Plain in New Jersey. Vowinkel (1984) presented aggregate ground-water withdrawal data for the New Jersey Coastal Plain. Zapecza (1984) presented the results of an intensive study of borehole geophysical logs of the New Jersey Coastal Plain and defined the occurrence and configuration of regional hydrogeologic units. Walker (1983) and Eckel and Walker (1986) documented and evaluated changes in water levels in the major artesian aquifers of the New Jersey Coastal Plain.

Navoy and others (U.S. Geological Survey, written commun., 1988) are studying the ground-water hydrology of Camden County and vicinity. The main purpose of their study is to examine the flow of ground water in the Potomac-Raritan-Magothy aquifer system. The study will define the geologic framework and hydraulic properties of the aquifer system and describe characteristics of flow, interaction of the aquifer system with the Delaware River estuary and overlying aquifers, and water use. The findings of the investigation will be used to develop a detailed three-dimensional model of



Base from U.S. Geological Survey
State base map, 1:500,000

Figure 1.--Location of study area.

ground-water flow in the Camden area. This study also will assess the need for and feasibility of modeling contaminant transport (Leahy and others, 1987).

Luzier (1980) developed a two-dimensional model of ground-water flow in the Potomac-Raritan-Magothy aquifer system to evaluate the effects of increasing water use. Using Luzier's model, Harbaugh and others (1980) tested various conjunctive-use strategies to determine the resulting potentiometric surface. A model prepared by Camp Dresser McKee, Inc. (1982) for the Delaware River Basin Commission was used to simulate flow in the Coastal Plain of New Jersey, Pennsylvania, and parts of Delaware. The New Jersey subregional Regional Aquifer System Analysis project includes a detailed investigation of the geohydrologic framework, geochemistry, and regional flow systems of major aquifers in the New Jersey Coastal Plain (Meisler, 1980; Martin, 1987).

Langmuir (1969), Farlekas and others (1976), Fusillo and Voronin (1981), and Fusillo and others (1985) conducted regional or county reconnaissance studies of ground-water quality that included the Swope Oil study area. Water samples, chiefly from the Potomac-Raritan-Magothy aquifer system, were collected for each study and were analyzed for various chemical constituents including purgeable organic compound and trace metals. Fusillo and others (1984) compiled ground-water quality data collected from 1923 to 1983 for part of the Potomac-Raritan-Magothy aquifer system in southwestern New Jersey.

The Swope Oil Superfund site has been studied since 1984. An analysis of aerial photographs of the Swope Oil Superfund site taken between 1965 and 1983 was prepared by the Bionetics Corporation (1984) for the USEPA. The NUS Corporation conducted a Remedial Investigation/ Feasibility study at the Swope Oil Superfund site during 1984-85. NUS Corporation installed five monitoring wells and eight test holes to obtain geologic and geophysical logs, cores of the lower confining unit, slug-test data, samples for water-quality and soil-chemistry analyses, and water levels (NUS Corporation, 1985). As part of an ongoing study, ERT, a contractor to the responsible parties, investigated the occurrence of polychlorinated biphenyls (PCBs) in shallow soils and conducted a terrain conductivity survey at this site during October 1987 (Phillip Guarraia, U.S. Environmental Protection Agency, Region II, oral commun., 1988).

Hydrogeologic investigations are currently being conducted at three additional waste-disposal sites in the study area--the Pennsauken Township Landfill, Aluminum Shapes, and Remanufactured Engines and Auto Parts. These investigations include installing wells and test holes, defining hydrogeologic units and hydrologic conditions, measuring water levels, and evaluating the quality of ground water (G. Haag, New Jersey Department of Environmental Protection, oral commun., 1987). Some of the data collected at these three sites have been obtained from the NJDEP and consulting firms and are included in this report.

Well-Numbering System

Two well-numbering systems are used in this report. The first, based on the well-numbering system used by the U.S. Geological Survey in New Jersey

since 1978, consists of a county code number (first two digits), followed by a sequence number of the well within the county (last four digits). County codes used are Burlington (5) and Camden (7). For example, well number 070372 represents the 372nd well inventoried in Camden County. Construction details for wells with this type of identifier are stored in the U.S. Geological Survey Ground Water Site Inventory (GWSI) data base.

The second well-numbering system consists of a three-digit well number used only in this report. This well-numbering system was developed for this report and is not used by either NJDEP or NUS Corporation. These well numbers are used to identify wells located in Camden County (for example, well number 021) that have not yet been entered into the GWSI data base.

Acknowledgments

The authors gratefully acknowledge the assistance of NJDEP in providing hydrogeologic data for ground-water contamination sites and results of chemical analyses of water from public-supply wells in the study area. James Anderson Associates and Woodward Clyde Consultants generously provided data on slug-tests conducted in the study area.

DESCRIPTION OF STUDY AREA

The Swope Oil study area includes approximately 10.5 square miles in Pennsauken Township, Camden County, and the Palmyra Borough and Cinnaminson Township, Burlington County, New Jersey (fig. 1 and pl. 1a). The Swope Oil Superfund site is a 1.9-acre triangular site situated between two railroad spurs and National Highway in an industrial park in the center of the study area (pl. 1a). Bordering the study area to the northeast are Palmyra Borough and Cinnaminson Township. The study area extends southeast to Maple Shade Township. The Delaware River borders the study area to the northwest. The study area has gently rolling hills and low-lying topography with altitudes that range from sea level to slightly more than 80 ft (feet) above sea level. Land use is primarily commercial, industrial, and residential.

The Swope Oil study area is situated within the Delaware River basin. The Delaware River is an estuary from Trenton, New Jersey to the Atlantic Ocean; the river and the lower reaches of its tributaries are tidally influenced in the study area. Delaware River tide elevations in the study area are measured at the U.S. Geological Survey tide-gaging station, Delaware River at Palmyra, New Jersey near the Tacony-Palmyra Bridge (pl. 1a). From October 1985 to September 1986, elevations ranged from a maximum high tide of 6.56 ft above sea level during May to a minimum low tide of 3.94 ft below sea level during January and March (Bauersfeld and others, 1987).

In the study area, the Delaware River Basin is divided into the Pennsauken, Baldwin Run, and Pomperston drainage basins (Vowinkel and Foster, 1981). Surface water in the study area drains into the Delaware River. The primary stream, Pennsauken Creek, is located in the northern part of the study area. North Branch and South Branch are streams in the

eastern part of the study area that meet to form Pennsauken Creek (pl. 1a). Pochack Creek is a smaller stream located in the southern part of the study area. Because these perennial streams are tidal throughout most of the study area, base flows have not been estimated.

Swope Oil Site Operations

A chemical reclamation facility operated from 1965 to 1979 (pl. 1b) at the Swope Oil Superfund site. Various chemical compounds were stored and/or processed at this facility. These chemical compounds include phosphate-ester hydraulic fluid, paints, varnishes, solvents, plasticizers, and printing inks. On-site features include a main building that served as an office and warehouse, a distilling house, a diked tank farm consisting of approximately 15 above-ground tanks, an unlined lagoon, and an area of buried sludge (NUS Corporation, 1985). The unlined lagoon has an irregular oval shape, and is approximately 120 ft long with a maximum width of 60 ft. The buried sludge area is approximately 160 ft by 100 ft. The depths of the lagoon and buried sludge area have not been reported.

In 1975, an inspector from the State Bureau of Air Pollution visited the site and recommended that the Bureau of Water Pollution Control inspect the site. During subsequent visits, officials observed discharges to drainage ditches on the site and probable migration toward Pennsauken Creek via storm sewers. Swope Oil Chemical Company was cited in 1975 for operating without proper permits and again in 1979 for failure to prepare, maintain, or fully implement a Spill Prevention, Containment and Countermeasure Plan. The company ceased operation in December 1979, and has declined to take any action at the site (NUS Corporation, 1985). To date, surface drums and approximately 3,000 tons of sludge from the on-site waste lagoon have been removed and a fence has been installed on the perimeter of the site (Geraghty and Miller, Inc., 1987), and approximately 75 percent of the above-ground tanks have been removed and building demolition has been initiated (T. Dunkelman, U.S. Environmental Protection Agency, oral commun., 1989).

Public-Supply Wells

Water used for public supply in the study area is derived from ground water. Of the five well fields in the study area, the Puchack, Delair, and Morris well fields are owned by the Camden City Water Department, and the Marion and Park Avenue fields are owned by the Merchantville-Pennsauken Water Commission (MPWC) (pl. 1c). In addition, National Highway well 1 and National Highway well 2 (well numbers 070372 and 070602) are owned by the MPWC, and the DVWC 28 (well number 050123) and the Stephen Drive well (well number 050124) are owned by the Delaware Valley Water Company (pl. 1a). Pumpage is concentrated primarily along the Delaware River. During 1983, public-supply wells in the study area pumped approximately 25 Mgal/d (million gallons per day) of water from the lower aquifer of the Potomac-Raritan-Magothy aquifer system within the Swope Oil study area. Approximately 30 percent of all ground-water withdrawals from public-supply wells in Camden County occur within a one-mile radius of the Swope Oil Superfund site. Withdrawals by public-supply purveyors in the study area are listed in the section "Data base."

Two public-supply wells, National Highway well 1 and National Highway well 2 (pl. 1a), are adjacent to the Swope Oil Superfund site. National Highway well 1, 250 ft southwest of the site, is contaminated with organic compounds and operates only during emergencies. During 1987, about 1.15 Mgal/d were withdrawn from National Highway well 2, approximately 1,400 ft northeast of the site.

Waste-Disposal Sites

The locations of four waste-disposal sites with observation-well networks in the study area are shown on plate 1c. The New Jersey Pollutant Discharge Elimination System (NJPDES) permit, observation-well, and select test-boring numbers for waste-disposal sites are listed in table 1. Observation-well and test-boring data from the four sites, drilled between 1979 and 1986, are listed in the section "Data Base".

HYDROGEOLOGIC FRAMEWORK

Regional Stratigraphy

The study area is in the New Jersey part of the Atlantic Coastal Plain physiographic province, a wedge of unconsolidated sediments that thickens and dips toward the Atlantic Ocean. This physiographic province is bounded on the northwest by the Fall Line (fig. 1).

The study area is located within the lowland subprovince of the Coastal Plain (Owens and Minard, 1979), an area characterized by stream valleys, tidal marshes, and swamp deposits at altitudes that are generally less than 20 ft above sea level. Areas at higher elevations are much sandier and have better drainage than the low-lying areas.

The study area is underlain by alluvial deposits; the Merchantville Formation of Cretaceous age that forms the Merchantville-Woodbury confining unit; and the Magothy Formation and the underlying Raritan Formation and the Potomac Group, all of Cretaceous age, that form the Potomac-Raritan-Magothy aquifer system. The Woodbury Clay crops out just east of the study area. These units lie unconformably on pre-Cretaceous bedrock that consists of metamorphic and igneous rocks (table 2).

Alluvial deposits of late Cenozoic age cover that part of the Delaware River Valley in which the study area is located. These deposits were described by Owens and Minard (1979). In the study area, the upper Cenozoic deposits range in age from Quaternary to Tertiary. These deposits consist of several geologic units--late Wisconsin and Holocene Delaware River alluvial deposits and fill; the Pleistocene Van Sciver Lake beds and Spring Lake beds; and possibly the upper Miocene Pensauken Formation.

Late Wisconsin and Holocene alluvial and fill deposits occur in the Delaware River channel and tidal wetlands. Tidal wetlands deposits consist of dark silt and clay mixed with organic matter and are sufficiently permeable to allow appreciable recharge and discharge to pass through them (Parker and others, 1964). The Pleistocene deposits are graywacke sands deposited in a broad valley bordering the present-day Delaware River channel. The Pensauken Formation occurs southwest of the Pleistocene

Table 1.--New Jersey pollutant discharge elimination system permit, observation-well, and selected test-boring numbers for waste-disposal sites in the Swope Oil study area

[--- indicates no data available. Source of information: New Jersey Department of Environmental Protection hazardous-waste files]

Waste-disposal site[1]	NJPDES permit number[2]	Test-boring number[3]	Observation-well number[4]
Swope Oil Superfund Site	---	006 007 008 009 010 011 012 013	001 002 003 004 005
Pennsauken Township Landfill	0054470	034 035 036 037	014 015 016 017 018 019 020 021 022 023 024 025 026 027 028 029
Aluminum Shapes	0034576	---	038 039 040 041
Remanufactured Engines and Auto Parts	0054046	---	042 043 044 045 046

[1] Waste-disposal site locations shown on plate 1b.
[2] New Jersey Pollutant Discharge Elimination system permit number.
[3] Three-digit test-boring numbers were assigned to test borings not in the U.S. Geological Survey Ground Water Site Inventory (GWSI) data base. Shallow soil-boring locations are shown on plates 1a and 1c.
[4] Three-digit well numbers were assigned to wells not in the U.S. Geological Survey GWSI data base. Well locations shown on plates 1a and 1c.

Table 2.--Geologic and hydrogeologic units in the Swope Oil study area and vicinity

System	Geologic unit	Hydrogeologic unit	
Quaternary	Alluvial deposits	Undifferentiated	
Tertiary	Pensauken Formation		
Upper Cretaceous	Woodbury Clay	Merchantville-Woodbury confining unit	
	Merchantville Formation		
	Magothy Formation	Potomac-Raritan-Magothy aquifer system	Upper aquifer
			Confining unit
	Raritan Formation		Middle aquifer
			Confining unit
Lower Cretaceous	Potomac Group		Lower aquifer
Pre-Cretaceous	Metamorphic and igneous rocks	Bedrock confining unit	

Modified from Zapecza (1989).

deposits on a low-elevation plain 50 to 80 ft above sea level, and forms a band of sediments approximately 5 miles wide that has been mapped from Salem to Trenton, New Jersey. These deposits are primarily glauconitic and feldspathic sand and gravel (Owens and Minard, 1979).

The Merchantville-Woodbury confining unit overlies the Potomac-Raritan-Magothy aquifer system, and is comprised of the Merchantville Formation in the study area and the Woodbury Clay just east of the study area. The Merchantville-Woodbury confining unit consists of thick glauconitic clay and sand and is one of the least permeable confining units in the New Jersey Coastal Plain (Zapecza, 1984).

The Magothy and Raritan Formations and Potomac Group, the oldest deposits in the New Jersey Coastal Plain, consist of deposits of gravel, sand, silt, and clay. The Potomac-Raritan-Magothy aquifer system crops out in a narrow three- to five-mile wide band adjacent to the Delaware River in southwestern New Jersey and in the study area. In southern New Jersey, the Potomac-Raritan-Magothy aquifer system is composed of three major aquifers--the upper, middle, and lower aquifers (Zapecza, 1984). These aquifers are lithologically similar to the overlying alluvial deposits and are hydraulically connected to them.

The Potomac-Raritan-Magothy aquifer system lies on top of bedrock. The altitude of the top of the bedrock surface is shown in figure 2. Because the bedrock consists of relatively impermeable metamorphic and igneous rocks, it is not hydraulically connected to the aquifer system and acts as a confining unit (Barksdale and others, 1958).

Study Area

Maps, cross sections, and well-log interpretations from previous investigations of the hydrogeologic units throughout New Jersey (Zapecza, 1989) and in the Camden region (A.S. Navoy, U.S. Geological Survey, written commun., 1985) were used to develop generalized sections of the study area. Refinement of the regional framework was accomplished primarily through interpretation of additional gamma-ray geophysical logs done as part of this study. The following preliminary discussion of the hydrogeologic framework of the study area is based on section A-A′ and B-B′ (pl. 1d and 1e) and on regional trends developed by Owens and Minard (1979) and Zapecza (1984).

Alluvial deposits form a thin veneer of permeable sediments over the Cretaceous deposits in the study area. Based on reconnaissance mapping conducted by Owens and Minard (1979) in the Delaware Valley, the thickness of alluvial deposits is variable and can be as much as 55 ft or more. Sand and clay layers in these deposits are discontinuous over short distances, as illustrated in section C-C′ (fig. 3). Alluvial sand and gravel deposits are hydraulically connected to the underlying aquifer where they overlie aquifers of the Potomac-Raritan-Magothy aquifer system. Together these deposits form the water-table aquifer in the study area.

The Merchantville-Woodbury confining unit crops out in the study area east of National Highway 2 well (pl. 1c) and dips to the southeast. None of the logs available for wells in the study area penetrates this unit.

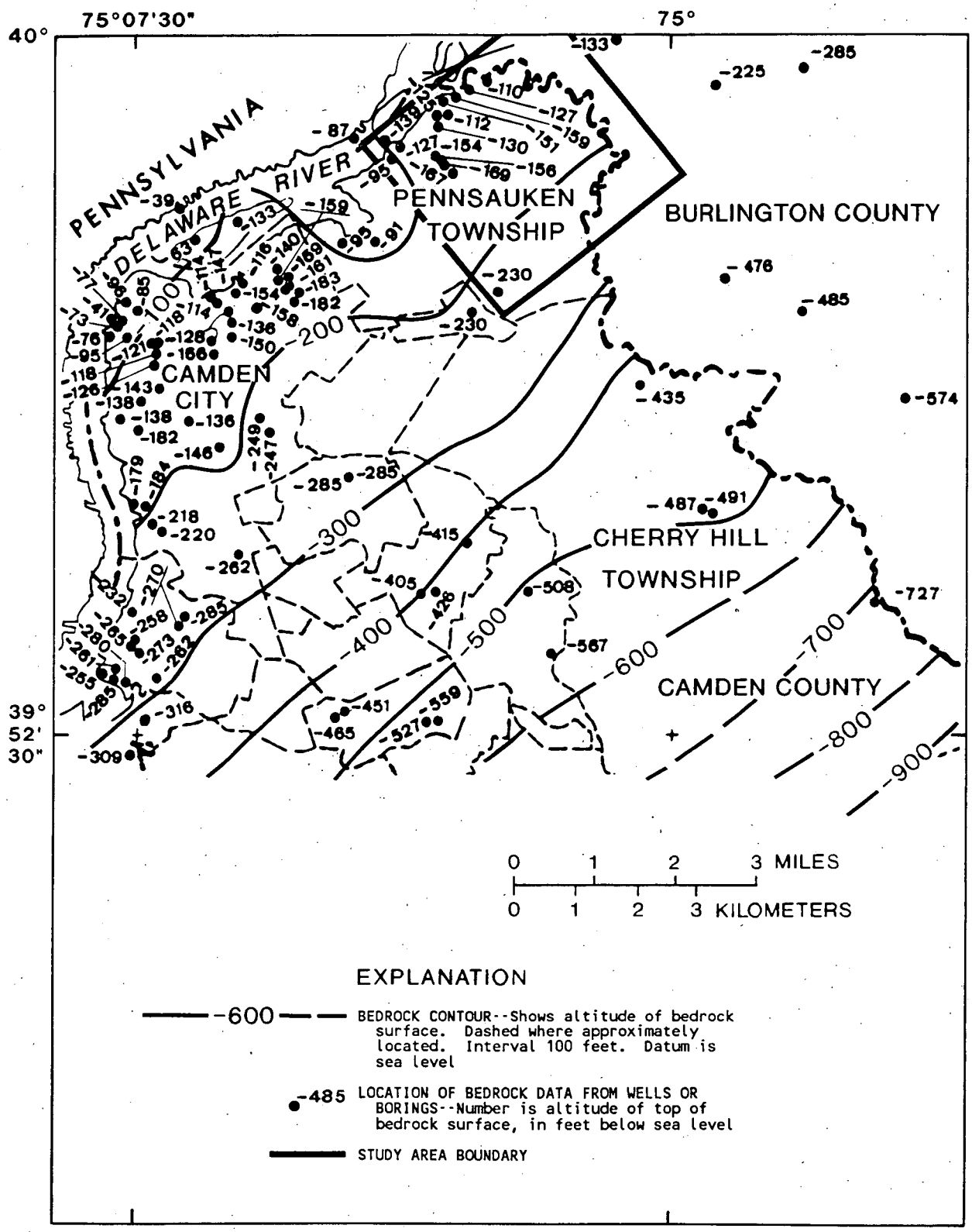


Figure 2.--Structure contours of the top of the bedrock surface beneath Coastal Plain sediments in Camden and Burlington Counties, New Jersey. (From Farlekas and others, 1976.)

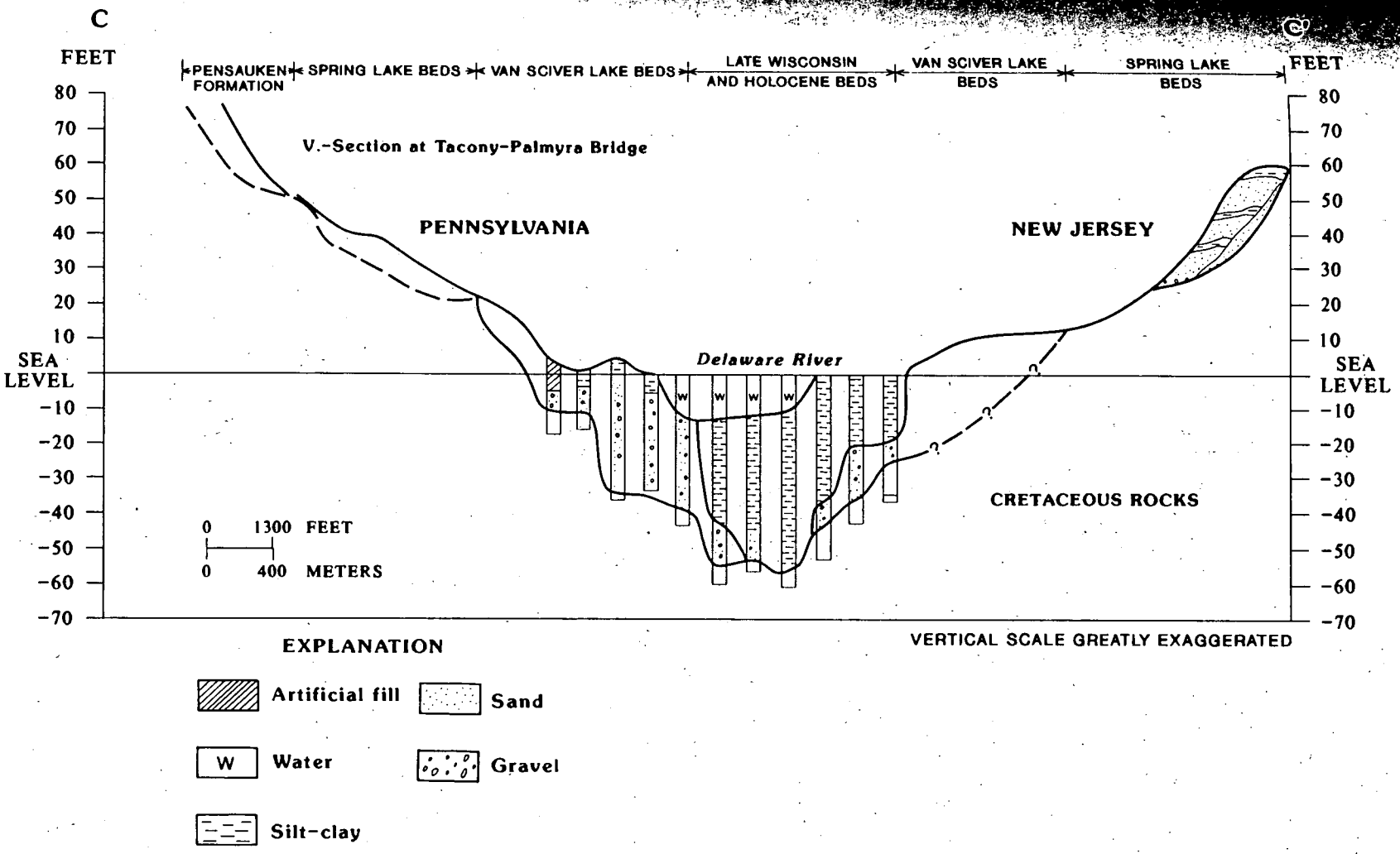


Figure 3.--Geologic section showing alluvial deposits in the Swope Oil study area and vicinity, New Jersey, and Pennsylvania. Line of section shown on plate 1a. (Modified from Owens and Minard, 1979, figure 29.)

The upper and middle aquifers of the Potomac-Raritan-Magothy aquifer system crop out where the discontinuous cover of alluvial deposits in the study area is absent. Both aquifers are incised by the Delaware River and are hydraulically connected to it. The upper and middle aquifers are differentiated in the southern part of the study area, where the upper aquifer is less than 20 ft thick and is considered to be a water-table aquifer, and the middle aquifer is confined and is approximately 20 ft thick.

In the rest of the study area, the upper and middle aquifers cannot be differentiated because the confining unit separating them is absent. This undifferentiated aquifer is a water-table aquifer that consists of numerous local silt and clay layers. The unsaturated and saturated parts of this unit together range from approximately 80 ft to greater than 100 ft thick. The confining unit that separates the middle, and the upper and middle undifferentiated aquifer, from the lower aquifer has a maximum thickness of 30 ft and appears to extend west to the Delaware River (A. S. Navoy, U.S. Geological Survey, oral commun., 1988).

The lower aquifer, which lies on top of bedrock, is approximately 45 to 110 ft thick and is hydraulically connected to the Delaware River throughout the study area. Altitude of bedrock east of the Delaware River in the study area ranges from approximately 75 to 250 ft below sea level.

Swope Oil Superfund Site

Only the water-table aquifer and the underlying confining unit at the Swope Oil Superfund site have been studied with test borings and wells. The unsaturated zone and the water-table aquifer are composed of alluvial deposits and the upper and middle undifferentiated aquifer of the Potomac-Raritan-Magothy aquifer system. From land surface to a depth of approximately 30 ft, the deposits consist primarily of interbedded sand, silt, and clay (NUS Corporation, 1985). Based on limited geologic framework analyses (fig. 3) conducted approximately 0.5 miles north of this site by Owens and Minard (1979), part or all of the upper 30 ft or so of sediments may be upper Cenozoic deposits. Below the surficial deposits to the top of the confining unit overlying the lower aquifer, sediments are coarse-grained and consist primarily of sand and some gravel with minor amounts of silt and clay. Several discontinuous clay lenses with thicknesses ranging from less than two to seven ft are present (NUS Corporation, 1985). The top surface of the confining unit separating the water-table and the confined aquifer is approximately 57 to 60 ft below sea level. The confined aquifer is the lower aquifer of the Potomac-Raritan-Magothy aquifer system.

Hydraulic Properties of Hydrogeologic Units

The vertical hydraulic conductivity of the Merchantville-Woodbury confining unit in the study area has not been evaluated. However, according to Martin (1987), the hydraulic conductivity of this unit may be as much as two orders of magnitude less than that reported for the confining units separating the aquifers of the Potomac-Raritan-Magothy aquifer system. The vertical hydraulic conductivity of the confining unit separating the upper and middle aquifers of the Potomac-Raritan-Magothy aquifer system in the study area has not been evaluated. A regional estimate for this unit based

on Martin's (1987) data is 2.0×10^{-2} ft/d. Two vertical hydraulic conductivity values, 1.47×10^{-4} ft/d and 1.28×10^{-3} ft/d, for the confining unit overlying the lower aquifer beneath the Swope Oil Superfund site has been reported by NUS Corporation (1985). A regional estimate of hydraulic conductivity for this unit based on Martin's (1987) data is 4×10^{-3} ft/d.

Aquifer-test analyses in Camden and Burlington Counties, summarized by Martin (1987), show that the horizontal hydraulic conductivity of the aquifers in the Potomac-Raritan-Magothy aquifer system, including alluvial deposits, ranges from 130 to 350 ft/d. Horizontal hydraulic conductivity of the upper and middle undifferentiated aquifer beneath the Swope Oil Superfund site was determined by NUS Corporation (1985) to range from 14 to 1,360 ft/d. In the study area, the average yield of wells (6-in. diameter or larger) screened in the lower aquifer is approximately 1190 gal/min (gallons per minute); specific capacity ranges from 6 to 80 gal/min/ft (gallons per minute per foot) of drawdown. Slug-test data and specific-capacity-test data are presented in Appendixes A and B, and table 3.

GROUND WATER

The most productive source of ground water in the Swope Oil study area is the Potomac-Raritan-Magothy aquifer system. Ground-water withdrawals in the study area are primarily from the lower aquifer in this system (Farlekas and others, 1976). The main source of recharge to the unconfined aquifer system is precipitation. Mean annual precipitation is about 44 in. (Vowinkel and Foster, 1981). Because the terrain is generally flat and covered with permeable, sandy soils, a significant percentage of the precipitation infiltrates into the ground-water reservoir. Induced recharge into the Potomac-Raritan-Magothy aquifer system from the Delaware River and downward leakage of water through confining units toward pumping centers in Camden County are the primary sources of recharge to the confined lower aquifer.

Flow

Prior to development, the natural ground-water flow regimen was influenced by topography. Recharge to the aquifer system was from precipitation on the topographically high areas of the outcrop northeast of Trenton, New Jersey. Ground-water flowed from these areas toward discharge areas that included the Delaware River and, to some extent, the topographic lows or stream valleys that cut across the outcrop (Farlekas and others, 1976).

Ground-water diversion has increased steadily since the early 1900's (Farlekas and others, 1976, fig. 15). By 1965, ground-water levels were below sea-level. The large withdrawal of water from the Potomac-Raritan-Magothy aquifer system reversed natural direction of flow, so that ground water flowed toward major cones of depression rather than toward the Delaware River (figs. 4 and 5). Cones of depression are centered in north-central Camden County, where water levels in 1983 were as low as 96 ft below sea level (Eckel and Walker, 1986). Heads in the aquifer system are currently below the stage of the Delaware River.

Table 3.--Summary of selected specific-capacity-test data from the Swope Oil study area

[Data from U.S. Geological Survey Ground-Water Site Inventory; gpm, gallons per minute; --, data not available]

Well number[1]	Owner	Local number	Date of test	Duration (hours)[2]	Discharge (gpm)	Drawdown (feet)	Specific capacity (gpm/foot)
050123	DELA VALLEY WC	DVWC 28	02-24-69	1	1200	38	32
050124	DELA VALLEY WC	STEPHENS DR	02- -70	--	1002	17	59
070332	MCHVL-PNSK WMC	MARION 2	--	8	1005	43	23
070335	MCHVL-PNSK WMC	MARION 1	07-03-57	8	1020	39	26
070346	MCHVL-PNSK WMC	PARK AVE 3A	01-31-40	24	720	20	36
070349	MCHVL-PNSK WMC	PARK AVE 1	11-24-47	8	1005	20	50
070350	MCHVL-PNSK WMC	PARK AVE 2	10-13-43	--	1000	27	37
070359	CAMDEN CITY WD	PUCHACK 5	08-23-24	6	1000	49	20
070362	CAMDEN CITY WD	6-75	01-29-75	8	1287	23	56
070363	CAMDEN CITY WD	PUCHACK 2	--	6	1440	49	29
070364	CAMDEN CITY WD	TEST 1-70	05-01-70	8	542	21	26
070366	CAMDEN CITY WD	PUCHACK 1	10-16-24	6	1400	48	29
070367	CAMDEN CITY WD	PUCHACK 3	05-29-24	6	1175	67	18
070368	CAMDEN CITY WD	DELAIR 1	10-31-30	8	1680	21	80
070369	CAMDEN CITY WD	DELAIR 2	10-31-30	8	1330	75	18
070372	MCHVL-PNSK WCM	NATIONAL HWY 1	07-21-67	8	1000	29	34
070373	CAMDEN CITY WD	MORRIS 6	07-11-32	8	1700	46	59
070374	CAMDEN CITY WD	MORRIS 9	07-03-32	8	1900	28.5	68
070377	CAMDEN CITY WD	MORRIS 7	--	8	1680	32	53
070379	CAMDEN CITY WD	MORRIS 10	11-07-61	3	1450	35	41
070380	KINGSTON TRAP	TRAP RK IND 2	08-25-66	2	200	34.5	6
070381	KINGSTON TRAP	TRAP RK IND 1	09-14-55	2	125	8	17
070382	CAMDEN CITY WD	MORRIS 4A	--	8	1585	28	57
070386	CAMDEN CITY WD	MORRIS 3A	07-28-53	8	1000	34	29
070389	CAMDEN CITY WD	MORRIS 5NA	--	6	1450	46	32
070528	CAMDEN CITY WD	PUCHACK 7	01-29-75	8	1287	23	56
070530	MCHVL-PNSK WMC	4R-A	07-30-79	8	1515	34	45
070533	CADILLAC PET FOODS 1		08-14-82	4	300	10	30
070540	CAMDEN CITY WD	TW-7-79	02-07-79	6	608	12.3	49
070545	CAMDEN CITY WD	MORRIS 11	08-01-79	24	2030	46	44
070602	MCHVL-PNSK WC	NATIONAL HWY 2	09-01-82	8	1236	32	39

[1] Well locations shown on plate 1a.
[2] Estimated.

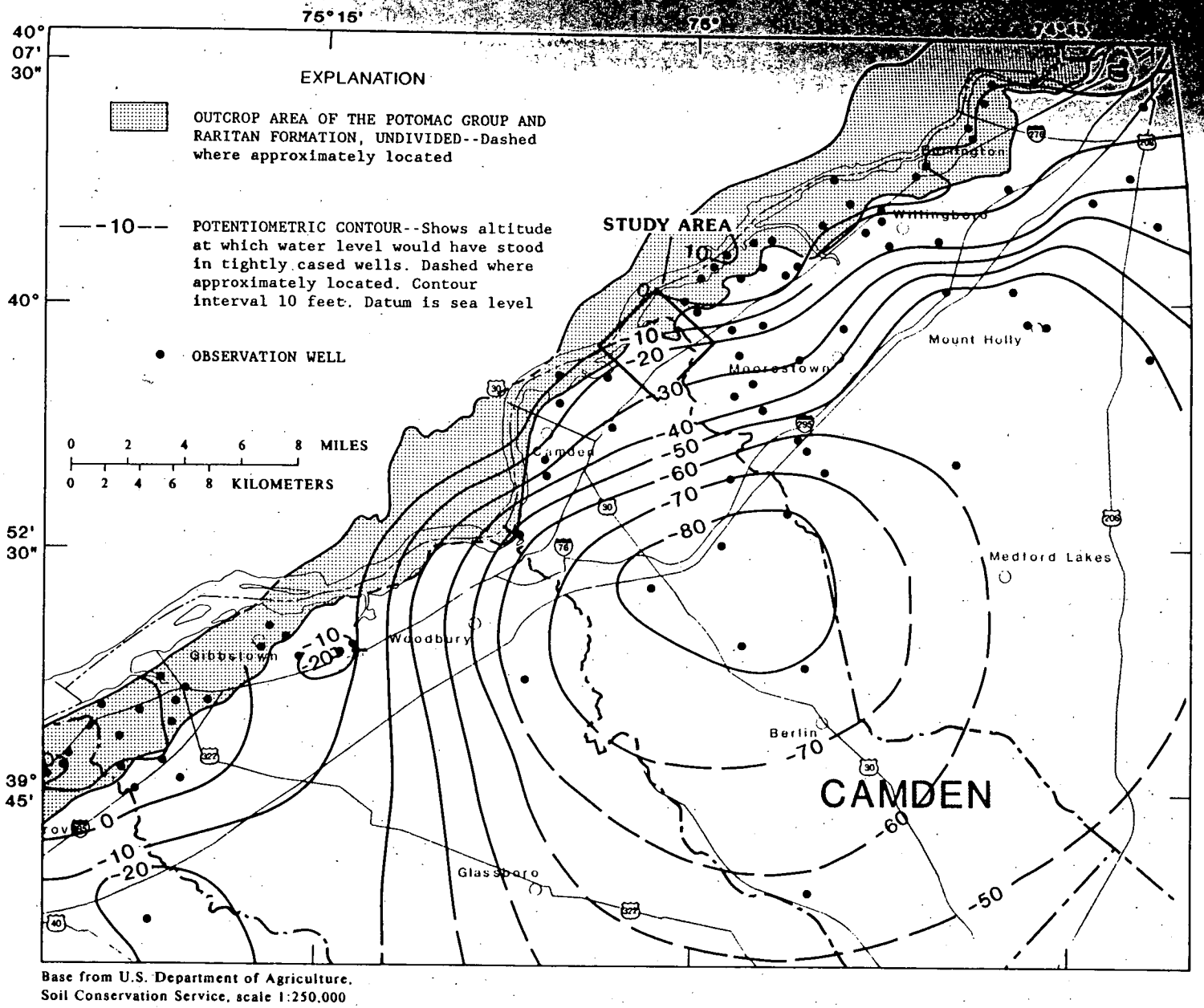
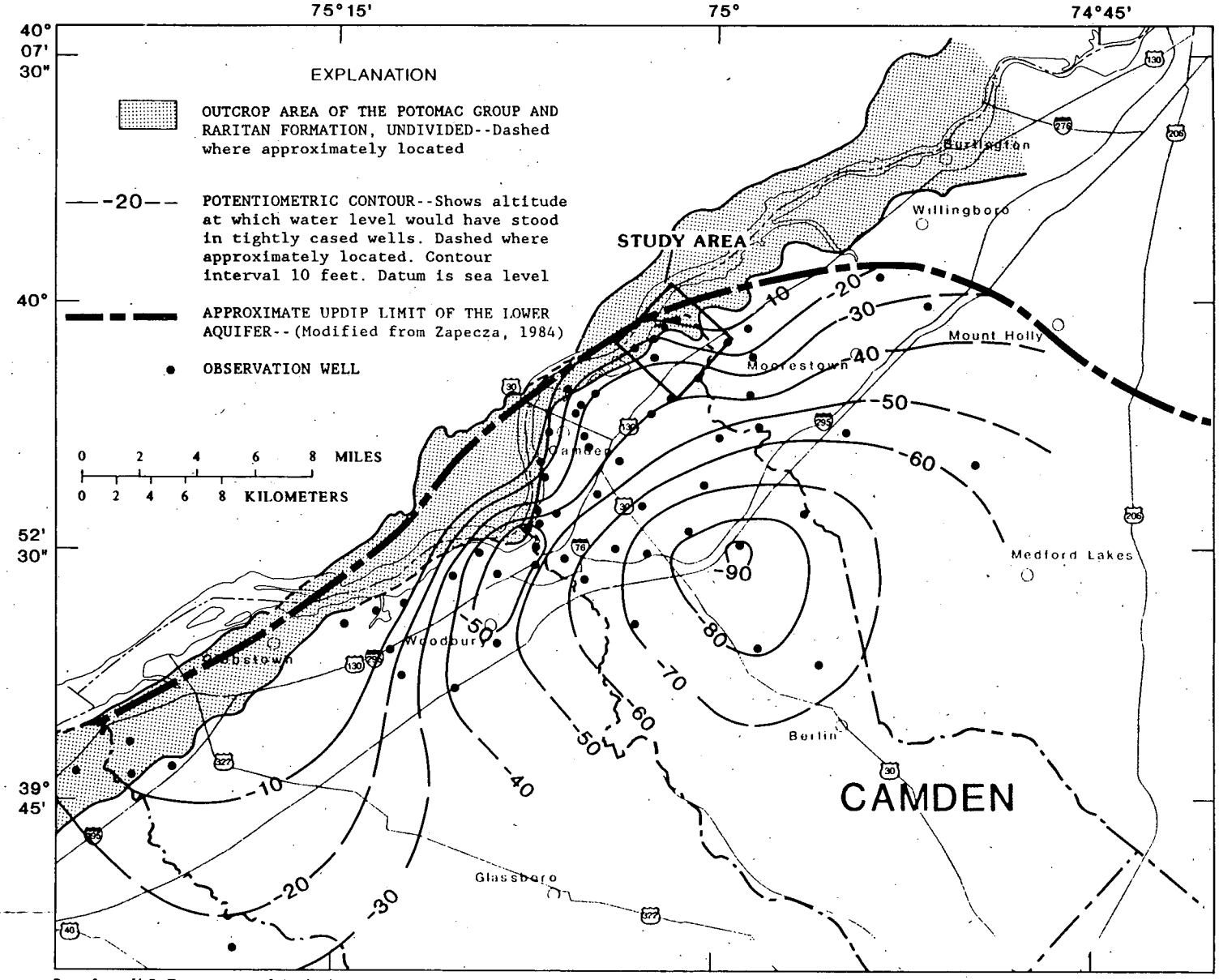


Figure 4.--Potentiometric surface of the middle aquifer and undifferentiated parts of the Potomac-Raritan-Magothy aquifer system, southwestern New Jersey, 1983. (Modified from Eckel and Walker, 1986, plate 2.)



Base from U.S. Department of Agriculture, Soil Conservation Service, scale 1:250,000

Figure 5.--Potentiometric surface of the lower aquifer of the Potomac-Raritan-Magothy aquifer system, southwestern New Jersey, 1983. (Modified from Eckel and Walker, 1986, plate 1.)

The Swope Oil study area is located on the northwestern edge of the cone of depression centered in Camden County. Water levels in the water-table aquifer (upper Cenozoic deposits, the upper aquifer, and upper and middle undifferentiated aquifers of the Potomac-Raritan-Magothy aquifer system) in the study area range from near sea level to greater than 20 ft below sea level. During a water-level-measurement program, conducted by the U.S. Geological Survey in 1986, water levels in the lower aquifer of the Potomac-Raritan-Magothy aquifer system in the study area ranged from 5 to 44 ft below sea level. Water levels in the water-table aquifer beneath the Swope Oil Superfund site during June 1984 to April 1985 ranged from 15.8 to 17.9 ft below sea level (NUS Corporation, 1985). The water level in the lower aquifer at the National Highway 1 well, 300 ft southwest of the site, was reported to be approximately 51 ft below sea level during 1984 (NUS Corporation, 1985), which is significantly lower than that found during the U.S. Geological Survey's 1983 synoptic water-level-measurement program (Eckel and Walker, 1986). It is not reported whether this measurement was taken under static or pumping conditions. Leakage from the water-table aquifer to the lower aquifer is likely the result of large withdrawals from the lower aquifer. The direction and hydraulic gradients of ground-water flow at the Swope Oil Superfund site have not been adequately determined.

Water-Level Fluctuations

Water levels in wells in the study area adjacent to the Delaware River and Pennsauken Creek are believed to show a cyclic fluctuation in response to changes in river levels caused by the ocean tides. Tides produce water-level fluctuations in the water-table aquifers by generating a flux of water into and out of the aquifer. Tides produce water-level fluctuations in confined aquifers by pressure loading.

Rush (1968) reported maximum tidal fluctuations of approximately 3 ft in wells screened in the water-table aquifer adjacent to the Delaware River near the study area. Whether ground water at the Swope Oil Superfund site is influenced by tides is unknown. Water-level fluctuations at the site, if any, would be considerably less than those in wells closer to the Delaware River. Ground-water levels in the study area also fluctuate in response to changes in withdrawal rates of public-supply and industrial wells, to precipitation (only in the water-table aquifer), and to changes in barometric pressure.

Quality

Sample-Collection and Laboratory Analytical Methods

Water-quality data available from 53 selected wells in the study area were compiled from information collected by the U.S. Geological Survey, NUS Corporation, and NJDEP. Sampled wells and the type of analysis performed are listed in table 4. All water-quality data are presented in tables 5, 6, 7, and 8. These data were compiled from all sources without regard to sample-collection methods, laboratory analytical methods, or quality assurance/quality control. Data sources and methodology are referenced.

Methods of collection and analysis of U.S. Geological Survey data follow the accepted U.S. Geological Survey water-sample-collection and laboratory

ew Jersey, 1983. (Modified from Eckel and Walker, 1986, plate 1.)

Table 4.--Wells with water-quality data by type from 1980-87 in the Swope Oil study area

Well number[1]	Local name	Analysis type
CAMDEN CITY WATER DEPARTMENT		
070363	Puchack 2	I, M, P, B/N
070366	Puchack 1	I, M, P
070367	Puchack 3	I, M, P
070368	Delair 1	I, M, P
070369	Delair 2	I, M, P
070370	Delair 3	I, M, P
070373	Morris 6	I, M, P
070379	Morris 10	I, M, P
070386	Morris 3A	I, M, P
070545	Morris 11	I, M, P
070586	Morris 12	I, M, P
070587	Morris 13	I, M, P
070528	Puchack 7	I, M, P
070535	TW-1-79	I, M, P
DELAWARE VALLEY WATER COMPANY		
050123	DVWC 28	I, M, P
050124	Stephens Dr	I, P
MERCHANTVILLE-PENNSAUKEN WATER COMMISSION		
070335	Marion 1	I, M, P
070345	Park Ave 5	I, M, P, B/N
070350	Park Ave 2	I, M, P, B/N
070372	National Hwy 1	I, M, P, B/N
070602	National Hwy 2	I, M, P, B/N
USGS OBSERVATION WELLS		
050826	Tacony-Palm 1s	I
050827	Tacony-Palm 2	I
050829	Tacony-Palm 3s	I
RECREATIONAL WELL		
070559	SWIM 1	I, M, P
SWOPE OIL SUPERFUND SITE		
001	MW-1	I, M, P, B/N
003	MW-3	I, M, P, B/N
004	MW-4	I, M, P, B/N
005	MW-5	I, M, P, B/N
PENNSAUKEN TOWNSHIP LANDFILL		
014	MW-1	I, M, P, B/N
015	MW-2	I, M, P, B/N
016	MW-3	I, M, P, B/N
017	MW-3D	I, M, P, B/N
018	MW-4	I, M, P, B/N
019	MW-5	I, M, P, B/N
020	MW-5D	I, M, P, B/N
021	MW-6	I, M, P, B/N
022	MW-6D	I, M, P, B/N
023	MW-7	I, M, P, B/N
024	MW-8	I, M, P, B/N
025	MW-9	I, M, P, B/N
026	MW-10	I, M, P, B/N
027	MW-11	I, M, P, B/N
028	MW-11D	I, M, P, B/N
029	MW-12	I, M, P, B/N
ALUMINUM SHAPES INCORPORATED		
038	MW-1-55	I, M, P, B/N
039	MW-2-55	I, M, P, B/N
040	MW-3-65	I, M, P, B/N
041	MW-4-60	I, M, P, B/N
REMANUFACTURED ENGINES AND AUTO PARTS		
042	MW-1-55	I, M, P, B/N
043	MW-2-55	I, M, P, B/N
045	MW-3-65	I, M, P, B/N
046	MW-4-60	I, M, P, B/N

[1] Six-digit well numbers are U.S. Geological Survey unique well numbers; well-construction data are stored in the U.S. Geological Survey GWSI data base. Three-digit well numbers were assigned to wells not in the U.S. Geological Survey GWSI data base. Well locations shown on plates 1a and 1b.

I Physical properties and common ions

M Metals

P Purgeable organic compounds

B/N Base/neutral- and acid-extractable organic compounds

Table 8.--Results of analyses with detectable concentrations of base/neutral- and acid-extractable organic compounds in water from wells in the Swope Oil study area

[Dissolved constituents, in micrograms per liter; <, concentration of compound is less than the detection limit of 2 parts per billion; BD, compound not detected - detection limit not specified]

Well number[1]	Local name	Date	Source of data[2]	Naptha-lene	Bis (2-ethylhexl) Phthalate	Di-N Octyl Phthalate
			Swope Oil Superfund Site			
001	MW-1	07-12-84	NUS	BD	<2	<2
003	MW-3	07-12-84	NUS	BD	58	58
005	MW-5	07-12-84	NUS	BD	<8	BD
			Pennsauken Township Landfill			
014	MW-1	02-10-87	NJDEP	BD	30	BD
015	MW-2	02-10-87	NJDEP	BD	68	BD
019	MW-5	02-10-87	NJDEP	BD	16	BD
023	MW-7	02-10-87	NJDEP	BD	65	BD
025	MW-9	02-10-87	NJDEP	BD	38	BD
			Remanufactured Engines and Auto Parts			
042	MW-2	03-17-87	NJDEP	4	BD	BD
042	MW-2	06-11-87	NJDEP	3	BD	BD

[1] Three-digit well numbers were assigned to wells not in the U.S. Geological Survey GWSI data base.

[2] Source of data: NUS Corporation (NUS) and the New Jersey Department of Environmental Protection (NJDEP). Data presented were not verified or examined for quality assurance or quality control.

Table 9.--U.S. Environmental Protection Agency hazardous substance list

[The following compounds comprise the U.S. Environmental Protection Agency Hazardous Substance List, from NUS Corporation (1986)]

ORGANICS

acenaphthene
acenaphthylene
acetone
aldrin
anthracene
Aroclor 1016
Aroclor 1221
Aroclor 1232
Aroclor 1242
Aroclor 1248
Aroclor 1254
Aroclor 1260
benzene
benz(a)anthracene
benzo(b)fluoranthene
benzo(k)fluoranthene
benzoic acid
benzo(ghi)perylene
benzo(a)pyrene
benzyl alcohol
alpha-BHC
beta-BHC
delta-BHC
gamma-BHC
bis(2-chloroethoxy)methane
bis(2-chloroethyl)ether
bis(2-chloroisopropyl)ether
bis(2-ethylhexyl)phthalate
bromodichloromethane
bromomethane
4-bromophenyl phenyl ether
butyl benzyl phthalate
carbon disulfide
carbon tetrachloride
chlordane
p-chloroaniline
chlorobenzene
chlorodibromomethane
chloroethane
2-chloroethyl vinyl ether
chloroform
chloromethane
2-chloronaphthalene
2-chlorophenol
4-chlorophenyl phenyl ether
chrysene
ortho-cresol
para-cresol
4,4'DDD
4,4'DDE
4,4'DDT
dibenzo(a,h)anthracene
dibenzofuran
di-n-butyl phthalate
m-dichlorobenzene
o-dichlorobenzene
3,3'-dichlorobenzidine
1,1-dichloroethane
1,2-dichloroethane
1,1-dichloroethylene
dichloromethane
2,4-dichlorophenol
1,2-dichloropropane
cis-1,3-dichloropropene
trans-1,3-dichloropropene
dieldrin
diethyl phthalate
2,4-dimethylphenol
dimethyl phthalate
4,6-dinitro-o-cresol
2,4-dinitrophenol
2,4-dinitrotoluene
2,6-dinitrotoluene
di-n-octyl phthalate
di-n-propylnitrosamine
endosulfan sulfate
endosulfan I (alpha)
endosulfan II (beta)
endrin
endrin ketone
ethyl benzene
fluoranthene
fluorene
heptachlor
heptachlor epoxide
hexachlorobenzene
hexachlorobutadiene
hexachlorocyclopentadiene
hexachloroethane
2-hexanone
indeno(1,2,3-cd)pyrene
isophorone
methoxychlor
methyl ethyl ketone
2-methylnaphthalene
4-methyl-2-pentanone
2-methylphenol
4-methylphenol
napthalene
m-nitroaniline
o-nitroaniline
p-nitroaniline
nitrobenzene
2-nitrophenol
4-nitrophenol
N-nitrosodiphenylamine
pentachlorophenol
phenanthrene
phenol
pyrene
styrene
1,1,2,2-tetrachloroethane
tetrachloroethylene
toluene
toxaphene
tribromomethane
1,2,4-trichlorobenzene
1,1,1-trichloroethane
1,1,2-trichloroethane
trichloroethylene
2,4,5-trichlorophenol
2,4,6-trichlorophenol
vinyl acetate
vinyl chloride
total xylenes

METALS

aluminum
antimony
arsenic
barium
beryllium
cadmium
calcium
chromium
cobalt
copper
iron
lead
magnesium
manganese
mercury
nickel
potassium
selenium
silver
sodium
thallium
tin
vanadium
zinc

INORGANICS

cyanide

Table 10.--Maximum concentrations of metals and purgeable organic compounds in ground water in the Swope Oil study area, grouped by water purveyors and waste-disposal sites

[Drinking-water standards and maximum concentrations in micrograms per liter; --, water-quality data not available; BD, concentration of the constituent is less than the detection limit; (#), number of analyses that exceed drinking-water limits; SE, recommended drinking-water standards have not been established]

Metals and purgeable organic compounds detected in ground water	Drinking-water standards		Maximum concentrations and number of analyses that exceed drinking-water limits		
	USEPA maximum contaminant levels[1]	NJDEP[2]	Camden City Water Dept.	Delaware Valley Water Company	Merchantville-Pennsauken Water Commission
Aluminum	SE	SE	100	--	100
Arsenic	50	50	4	1	1
Barium	1,000	1,000	110	61	60
Berylium	SE	SE	3	BD	5
Cadmium	10	10	7	2	1
Chromium (Hexavalent)[3]	50	50	390(4)	1	BD
Cobalt	SE	SE	170	--	6
Copper[4]	1,000	SE	51	25	110
Lead	50	50	20	--	20
Mercury	2	2	0.48	--	1.9
Nickel	SE	SE	20	--	BD
Selenium	10	10	--	--	2
Silver	50	50	--	--	--
Thalium	SE	SE	BD	--	BD
Zinc[4]	5,000	SE	295	56	57
Benzene	SE	1	5(1)	BD	--
Bromoform	SE	SE	BD	BD	BD
Carbon Tetrachloride	SE	2	BD	BD	18(1)
Chlorobenzene	SE	4	10(1)	BD	BD
Chloroform	SE	SE	BD	BD	BD
Ethyl Benzene	SE	SE	BD	BD	BD
Methyl Chloride	SE	SE	BD	--	BD
Acrolein	SE	SE	--	--	--
1,3-Dichloropropene	SE	SE	BD	BD	BD
Methylene Chloride	SE	2	8(1)	BD	13(1)
Tetrachloroethylene	SE	1	5(2)	BD	5(1)
Toluene	SE	SE	6	BD	BD
Trichloroethylene	SE	1	64(6)	BD	150(8)
Vinyl Chloride	SE	5	4.6	BD	BD
1,1-Dichloroethylene	SE	2	6(2)	BD	BD
1,1-Dichloroethane	SE	SE	BD	BD	6
1,1,1-Trichloroethane	SE	26	BD	BD	14(1)
1,1,2,2-Tetrachloroethane	SE	SE	BD	BD	BD
1,2-Dichloroethane	SE	2	BD	BD	2
1,2-Dichloropropane	SE	SE	BD	BD	BD
Cis and Trans 1,2-Dichloroethylene	SE	10	25(2)	BD	53(2)
1,3-Dichlorobenzene	SE	600	BD	--	--
1,4-Dichlorobenzene	SE	6	BD	--	--
1,2-Dichlorobenzene	SE	600	BD	--	--
Total purgeable organic[5] compound--maximum concentration for a single well	SE	50	64(1)	BD	[6]162(6)

1 Taken from U.S. Environmental Protection Agency (1986).
2 Taken from U.S. Environmental Protection Agency (1977a), and proposed by the N.J. Department of Environmental Protection (Baker and Hamill, written commun., 1987).
3 NUS reported total dissolved chromium, refer to table 6.
4 U.S. Environmental Protection Agency recommended maximum contaminant level (U.S. Environmental Protection Agency, 1977b).
5 The number of purgeable organic compounds analyzed for in water samples is variable.
6 During 1988, total purgeable organic compounds in water from National Highway well 1 are approximately 300 micrograms per liter (Dick Brown, Merchantville-Pennsauken Water Commission, oral commun., 1988).

Table 10.--Maximum concentrations of metals and purgeable organic compounds in ground water in the Swope Oil study area, grouped by water purveyors and waste-disposal sites--Continued

[Drinking-water standards and maximum concentrations in micrograms per liter; --, water-quality data not available; BD, concentration of the constituent is less than the detection limit; (#), number of analyses that exceed drinking-water limits; SE, recommended drinking-water standards have not been established]

Metals and purgeable organic compounds detected in ground water	Maximum concentrations and number of analyses that exceed drinking-water standards				
	Recreational Well	Swope Oil Superfund site	Pennsauken Township Landfill	Aluminum Shapes Incorporated	Remanufactured Engines and Auto Parts
Aluminum	--	18,900	90	421	--
Arsenic	--	16	8	9	--
Barium	70	131	200	390	--
Beryllium	BD	2	1	--	33
Cadmium	1	1.1	8	10	17.(3)
Chromium (Hexavalent)	--	64(2)	1100(2)	6	56.(1)
Cobalt	8	16	40	--	--
Copper[3]	33	40	55	--	163
Lead	--	90(3)	47	--	89.(4)
Mercury	--	0.71	4.5(1)	4	--
Nickel	--	25	--	104	128
Selenium	--	--	8.6	--	--
Silver	--	--	--	--	11
Thalium	--	BD	--	--	1500
Zinc[3]	77	152	200	86	147
Benzene--	--	--	190(11)	72(4)	300(1)
Bromoform	--	--	BD	5	--
Carbon Tetrachloride	BD	--	24(3)	--	--
Chlorobenzene	--	BD	72(10)	48(3)	BD
Chloroform	BDK	--	7,600	BD	BD
Ethyl Benzene	--	--	300	180	BD
Methyl Chloride	--	--	10	BD	10
Acrolein	--	--	BD	10	BD
1,3-Dichloropropene	--	--	47	BD	BD
Methylene Chloride	BD	--	15(7)	BD	20(1)
Tetrachloroethylene	BD	42(3)	59(8)	67(1)	BD
Toluene	BD	BD	38	BD	400
Trichloroethylene	BD	BD	50(5)	BD	3,000(6)
Vinyl Chloride	--	BD	37(5)	25(1)	BD
1,1-Dichloroethylene	--	13(3)	BD	BD	310(2)
1,1-Dichloroethane	BD	BD	83	BD	1,000
1,1,1-Trichloroethane	BD	53(3)	16	BD	4,900(3)
1,1,2,2-Tetrachloroethane	--	BD	35	BD	BD
1,2-Dichloroethane	BD	BD	BD	BD	BD
1,2-Dichloropropane	--	BD	BD	BD	300
Cis and Trans 1,2-Dichloroethylene	BD	8	170(10)	115(2)	3,300(3)
1,3-Dichlorobenzene	--	BD	8	BD	BD
1,4-Dichlorobenzene	--	BD	17(2)	17(1)	--
1,2-Dichlorobenzene	--	--	63	BD	52
Total purgeable organic compounds--maximum concentration for a single well	BD	108(3)	451(10)	145(4)	35,140(5)

landfill, which is screened in the lower aquifer of the Potomac-Raritan-Magothy aquifer system, contains concentrations of POCs that exceed NJDEP recommended drinking-water criteria. The maximum concentration of total POCs[1] in water from wells at each waste-disposal site ranges from 108 µg/L (micrograms per liter) at the Swope Oil Superfund site to 35,140 µg/L at Remanufactured Engines and Auto Parts. Water in observation wells screened in the water-table aquifer at the Swope Oil Superfund site, Pennsauken Township landfill, and Remanufactured Engines and Auto Parts also contains base/neutral- and acid-extractable organic compounds.

At the Swope Oil Superfund site, four observation wells are screened in the water-table aquifer (upper and middle undifferentiated aquifer of the Potomac-Raritan-Magothy aquifer system). During 1984, concentrations of chromium and lead exceeded the USEPA MCL in two observation wells. The maximum concentration of chromium and lead in water from these wells is 64 µg/L and 90 µg/L. Concentrations of POCs in three wells exceed NJDEP recommended drinking-water criteria. Total POCs in water from these three wells range from 66 µg/L to 108 µg/L. POCs detected are 1,1,1-trichloroethylene, tetrachloroethylene, trichloroethylene, and 1,1-dichloroethylene (table 7). In addition, base/neutral- and acid-extractable organic compounds were detected in well MW-3 (pl. 1a, well number 003).

DATA BASE

Well Inventory

Table 11 presents selected information on 98 wells and 16 test borings in the Swope Oil study area (pl. 1a). This table includes data on construction, drillers' and geologists' logs, geophysical logs, water levels, well yield and aquifer tapped. Data on 64 wells and test borings were obtained from the U.S. Geological Survey GWSI data base, 41 were obtained from NJDEP files, and five were obtained from NUS Corporation (1985). Copies of selected drillers' and geologists' logs and geophysical logs made in 68 wells and 12 test borings are shown in Appendixes C and D. Many geologists' logs are based on cored lithologic samples inspected by geologists. Gamma-ray, single-point resistance and spontaneous potential logs are included in Appendix D. Because the geophysical logs have been reduced in size, some details may be missing. Copies of the original logs are available for public inspection at the New Jersey District office of the U.S. Geological Survey.

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[1] The number of POCs analyzed in water samples is variable.

Ground-Water Levels

Ground-water levels measured in 14 wells in the study area by the U.S. Geological Survey during regional synoptic ground-water measurement programs in 1984 and 1986 are listed in table 12. Ground-water levels measured in five observation wells by NUS Corporation during 1984 and 1985 at the Swope Oil Superfund site are listed in table 13. Water levels were measured using the wetted-steel-tape method or electric tape.

Accuracy of ground-water levels in this report depends on the method used to determine land-surface elevation at a well, and on the method used to measure water levels. Land-surface elevation at wells in the U.S. Geological Survey water-level network in the study area was estimated by visual inspection of U.S. Geological Survey 7 1/2-minute quadrangle maps that have a 10-ft contour interval. Land-surface elevation for wells at the Swope Oil Superfund site and at the other waste disposal sites were measured to within 0.01 ft by land surveyors. The U.S. Geological Survey ground-water-level measurements are less accurate than measurements taken at the Swope Oil Superfund site due to the inherent limitations of estimating land-surface elevations from a map.

Specific-Capacity and Slug Tests

Specific-capacity-test results and specific capacities for 30 wells in the study area with diameters equal to or greater than 6 in. are listed in table 3. Data are available only for the lower aquifer of the Potomac-Raritan-Magothy aquifer system. Specific capacity depends on the hydraulic characteristics of an aquifer and on the construction of a well. Specific capacity may be used to estimate the hydraulic conductivity of an aquifer (Heath, 1987).

Data from 14 slug tests conducted in observation wells at the Swope Oil Superfund site and the Pennsauken Township Landfill are shown in Appendix A and are listed in Appendix B. Slug tests provide information on the horizontal hydraulic conductivity of an aquifer. Hydraulic conductivities derived from slug tests are most representative of the hydraulic properties of the material adjacent to the well screen. Because slug tests stress a relatively small volume of the aquifer, they are less likely to include the pathways that control the effective hydraulic conductivity of the system (B. P. Sargent, U.S. Geological Survey, written commun., 1987).

NUS Corporation conducted slug tests in four wells screened in the water-table aquifer (upper and middle undifferentiated aquifer of the Potomac-Raritan-Magothy aquifer system) at the Swope Oil Superfund site using the vacuum method. These wells are screened below the water table. The water levels in each observation well were raised by creating a vacuum in the well. The vacuum was maintained for a short time so that the water level could stabilize. When the vacuum was released, a pressure transducer recorded water-level changes (NUS Corporation, 1985).

Woodward-Clyde Consultants conducted rising-head and falling-head slug tests in 10 wells screened in the water table and confined aquifers of the Potomac-Raritan-Magothy aquifer system at the Pennsauken Landfill. The water levels in each well were raised or lowered by adding a slug of water

Table 12.--Water levels in wells in the Swope Oil study area measured by the U.S. Geological Survey, 1984 and 1986

[ft, feet; mo/day, month and day; --, data not available]

Well number[1]	Owner	Local number	Altitude of land surface (ft)	Method of measurement		Water level			
						1984		1986	
				Land surface[2]	Water levels[3]	Altitude (ft)	Date (mo/day)	Altitude (ft)	Date (mo/day)
050123	Dela Valley WC	DVWC 28	25	M	S	-7	11/14	-11	8/27
070348	Mchvl-Pnsk WC	Park Ave 3	25	M	T	-35	11/19	-39	8/26
070359	Camden City WD	Puchack 5	30	M	S	-25	11/28	-30	8/28
070377	Camden City WD	Morris 7	10	L	S	-12	11/26	--	--
070379	Camden City WD	Morris 10	16	M	S	-10	11/28	-13	8/28
070382	Camden City WD	Morris 4A	8	M	--	--	--	-9	8/28
070390	Camden City WD	Morris 1	9	M	T	-3	11/28	-5	8/28
070528	Camden City WD	Puchack 7	20	M	S	-29	11/28	-33	8/28
070533	Cadillac Pet Food	[1]	8	M	--	-14	1/30	--	--
070535	Camden City WD	TW-1-79	10	M	S	-24	11/28	-23	8/28
070537	Camden City WD	TW-4-79	10	M	--	--	--	-30	8/28
070538	Camden City WD	TW-5-79	10	M	S	-39	11/28	-35	8/28
070539	Camden City WD	TW-6-79	10	M	S	-47	11/28	-44	8/28
070540	Camden City WD	TW-7-79	10	M	T	-29	11/28	-29	8/28

[1] Six-digit well numbers are USGS unique well numbers; well construction details are stored in the USGS GWSI data base. Well locations shown on plate 1a.

[2] Method of altitude of land surface measurement: (M) taken from USGS 7-1/2-minute quadrangle map with a 10-foot contour interval; (L) leveled in with surveying equipment.

[3] Method of water-level measurement(s): (S) wetted-steel-tape; (T), electric tape.

[4] Feet below sea level.

Table 13.--Water levels in wells at the Swope Oil Superfund site, 1984 and 1985

[Data from NUS Corporation, 1985; ft, feet; mo/day, month and day; --, data not available]

Well number[1]	Owner	Local number	Altitude of land surface (ft)	Water level[2,3,4] 1984 Altitude (ft)	1984 Date (mo/day)	1985 Altitude (ft)	1985 Date (mo/day)
001	Swope Oil Co.	MW-1	63.28	-16.18	06/13	-16.74	01/31
001	Swope Oil Co.	MW-1	63.28	-16.27	06/19	-17.52	03/05
001	Swope Oil Co.	MW-1	63.28	-16.05	06/27	-17.86	04/01
001	Swope Oil Co.	MW-1	63.28	-16.49	06/28	--	--
001	Swope Oil Co.	MW-1	63.28	-16.17	07/01	--	--
001	Swope Oil Co.	MW-1	63.28	-16.07	07/04	--	--
001	Swope Oil Co.	MW-1	63.28	-15.97	07/11	--	--
001	Swope Oil Co.	MW-1	63.28	-15.94	10/27	--	--
002	Swope Oil Co.	MW-2	63.39	-15.94	07/11	-16.92	01/31
002	Swope Oil Co.	MW-2	63.39	-15.79	10/27	-17.54	03/05
002	Swope Oil Co.	MW-2	63.39	--	--	-17.81	04/01
003	Swope Oil Co.	MW-3	64.10	-16.27	06/27	-16.98	01/31
003	Swope Oil Co.	MW-3	64.10	-16.64	06/28	-17.68	03/05
003	Swope Oil Co.	MW-3	64.10	-16.35	07/01	-17.86	04/01
003	Swope Oil Co.	MW-3	64.10	-16.28	07/04	--	--
003	Swope Oil Co.	MW-3	64.10	-16.15	07/11	--	--
003	Swope Oil Co.	MW-3	64.10	-15.98	10/27	--	--
004	Swope Oil Co.	MW-4	59.77	-16.13	06/13	-16.78	01/31
004	Swope Oil Co.	MW-4	59.77	-16.18	06/19	-17.51	03/05
004	Swope Oil Co.	MW-4	59.77	-16.13	06/27	-17.90	04/01
004	Swope Oil Co.	MW-4	59.77	-16.53	06/28	--	--
004	Swope Oil Co.	MW-4	59.77	-16.15	07/01	--	--
004	Swope Oil Co.	MW-4	59.77	-16.10	07/04	--	--
004	Swope Oil Co.	MW-4	59.77	-15.96	07/11	--	--
004	Swope Oil Co.	MW-4	59.77	-15.80	10/27	--	--
005	Swope Oil Co.	MW-5	63.27	-16.01	07/01	-16.81	01/31
005	Swope Oil Co.	MW-5	63.27	-15.94	07/04	-17.40	03/05
005	Swope Oil Co.	MW-5	63.27	-15.81	07/11	-17.78	04/01
005	Swope Oil Co.	MW-5	63.27	-15.94	10/27	--	--

[1] Three-digit well numbers were assigned to wells not in the USGS GWSI data base. Well locations shown on plate 1b.
[2] Water levels were measured using the electric-tape method and/or the wetted-steel-tape method.
[3] Feet below sea level.
[4] Data presented were not verified or examined for quality assurance or quality control.

to or removing a slug of water from the well. A pressure transducer coupled to a data logger recorded water-level changes (Woodward-Clyde Consultants, 1988).

Ground-Water Withdrawals

Ground-water withdrawals in the study area during 1973-87 are presented in table 14. Monthly and annual withdrawals are listed for individual public-supply wells or well fields. In the study area, well fields rather than individual wells are generally metered for withdrawals. Withdrawals from industrial wells in the study area are currently unavailable (G. M. Farlekas, U.S. Geological Survey, oral commun., 1988). Withdrawal data prior to the 1985 RI/FS study conducted at the Swope Oil Superfund site are presented for historical perspective.

Chemical Analyses

Results of 183 chemical analyses of water from 49 wells in the Swope Oil Superfund study area are shown in tables 5 through 8. These analyses include 44 chemical analyses of water collected from 29 observation wells at four waste disposal sites and three public supply wells during 1984-87 by consultants for the USEPA and NJDEP; and 139 chemical analyses of water collected from 23 wells during 1980-87 by the U.S. Geological Survey. Data listed in these tables are physical properties and common ions (table 5); trace metals (table 6); purgeable organic compounds (table 7); and base/neutral- and acid-extractable organic compounds (table 8).

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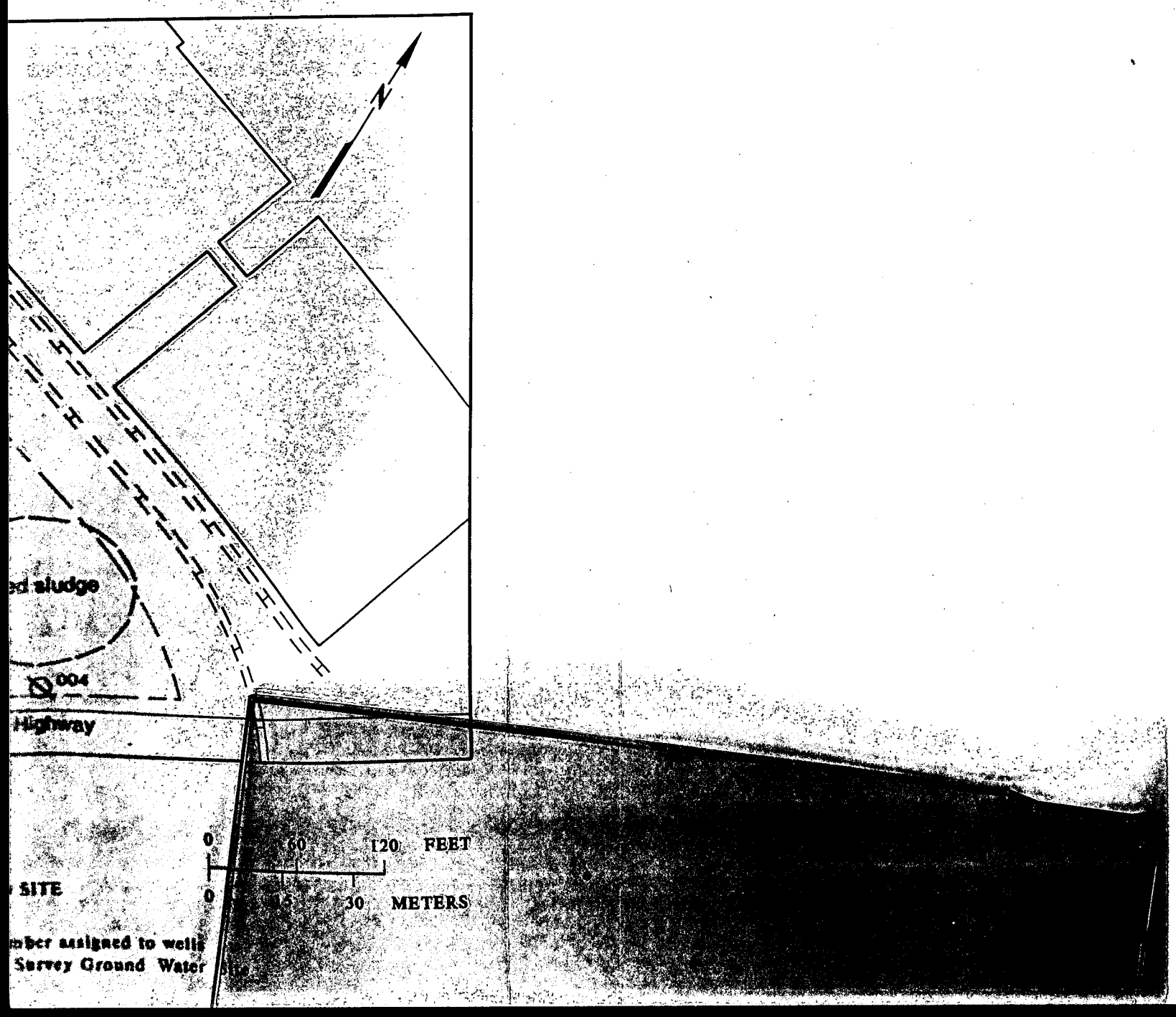
PLATE 1



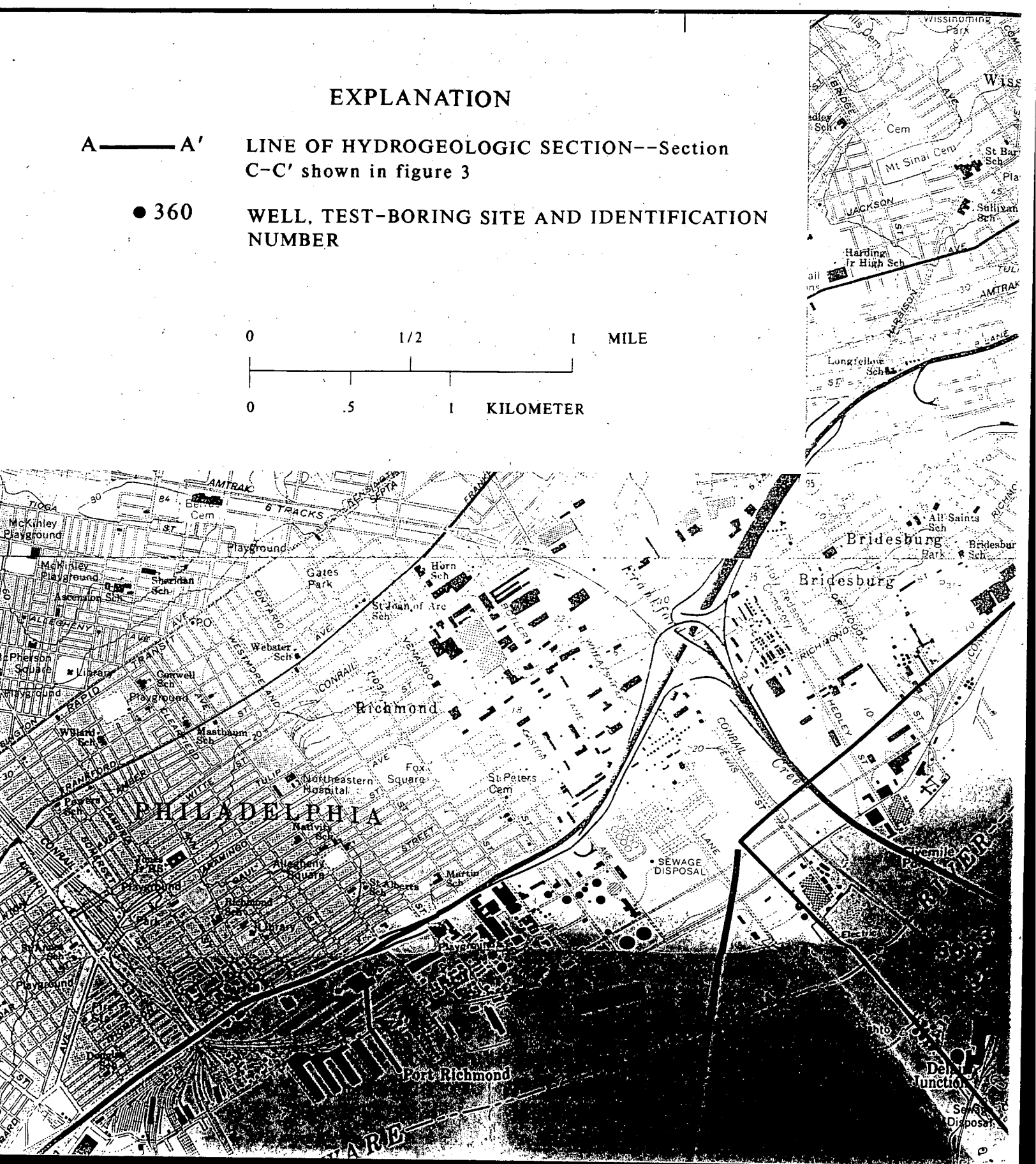
EXPLANATION

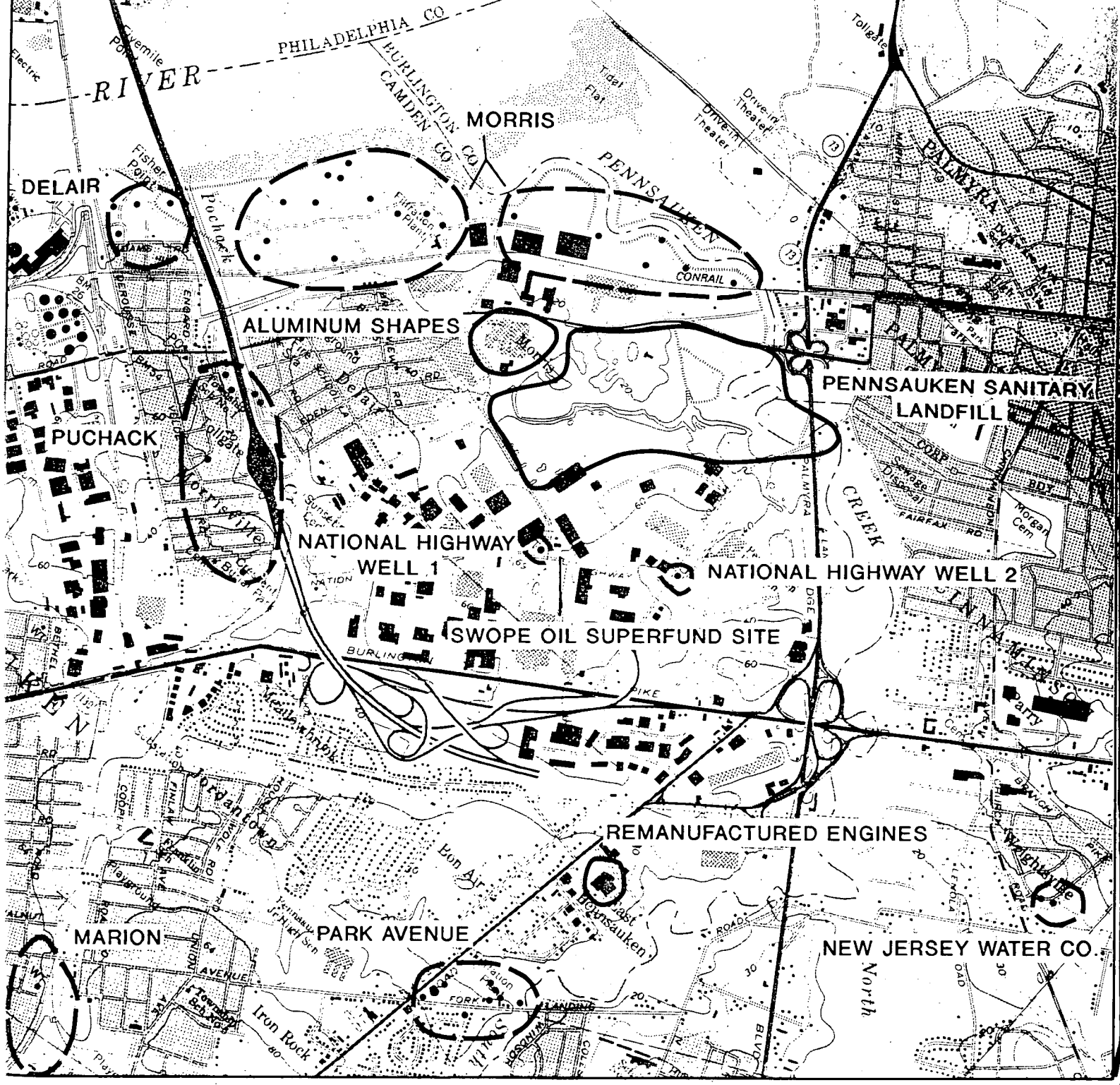
A——A′ LINE OF HYDROGEOLOGIC SECTION--Section C-C′ shown in figure 3

● 360 WELL, TEST-BORING SITE AND IDENTIFICATION NUMBER

0 1/2 1 MILE

0 .5 1 KILOMETER





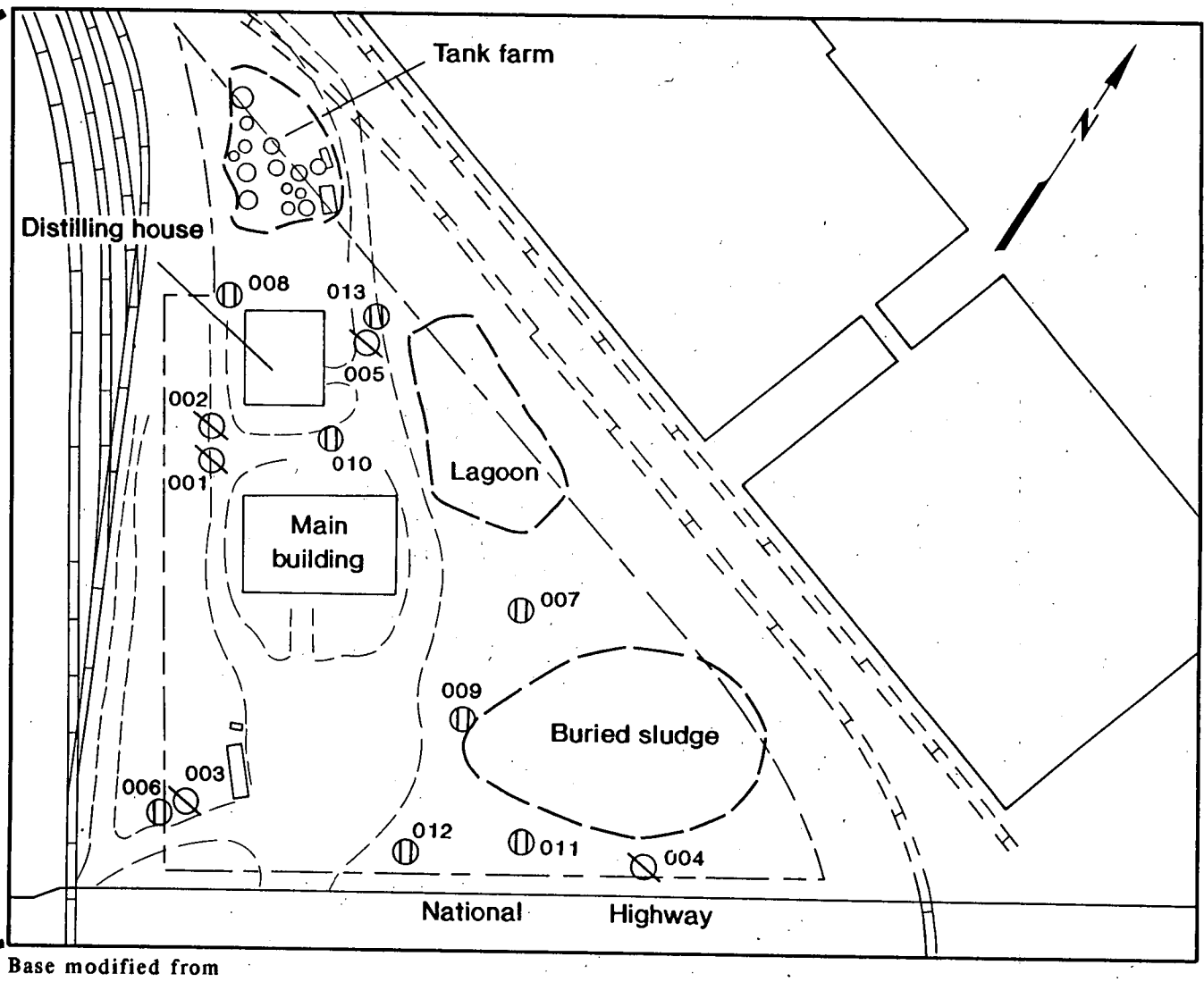
EXPLANATION

- Boundary of public-supply well field
- Boundary of waste-disposal site
- • Public-supply well

0 1/2 1 MILE

0 .5 1 KILOMETER

1c. Location of public-supply well fields and waste-disposal sites with observation-well networks.



Base modified from
NUS Corporation, 1985

EXPLANATION

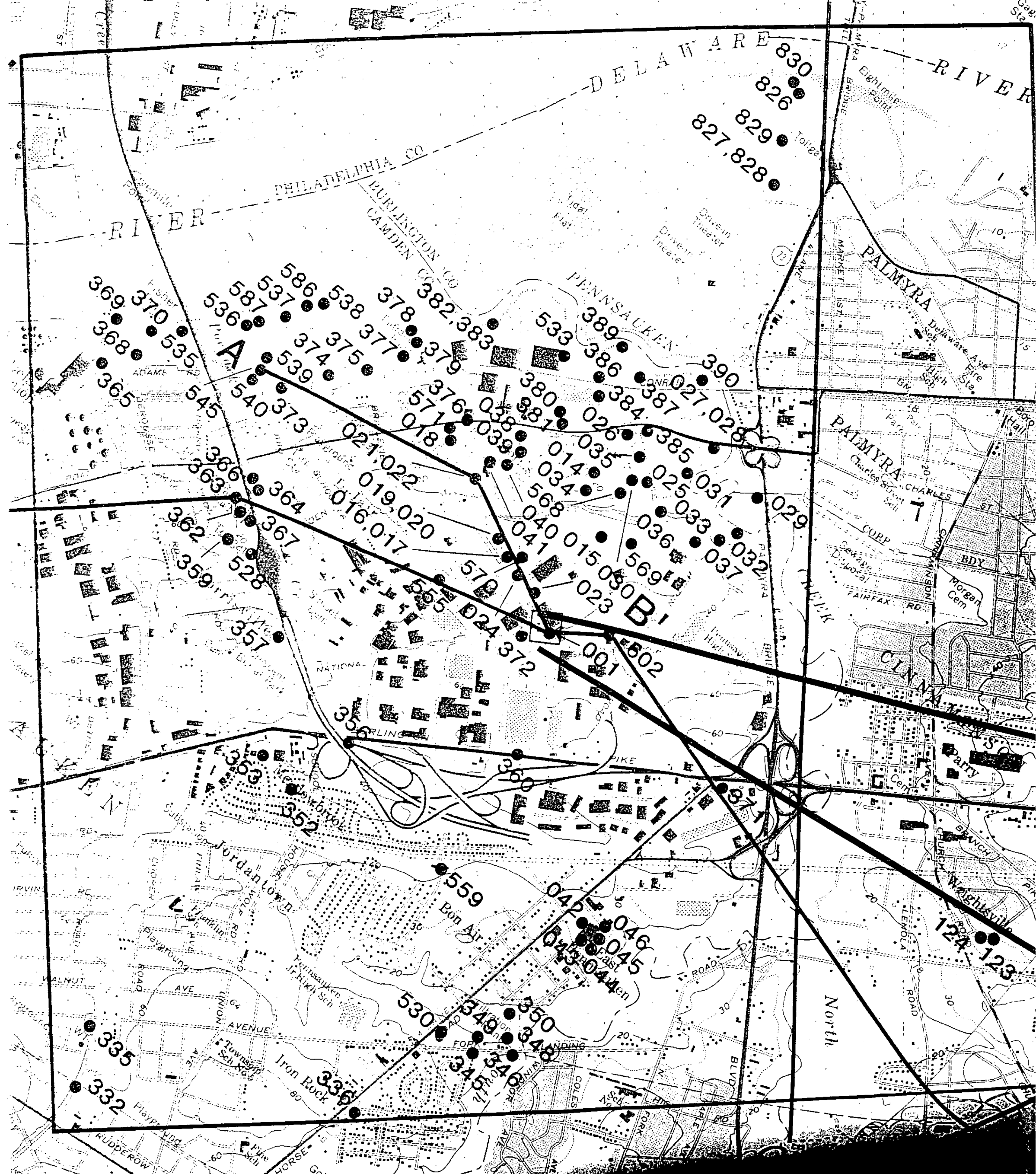
0 60 120 FEET
0 15 30 METERS

BOUNDARY OF SWOPE OIL SUPERFUND SITE

011 TEST BORING--Number is three-digit number assigned to wells and test borings not in the U.S. Geological Survey Ground Water Site Inventory data base

004 OBSERVATION WELL--Number is three-digit number assigned to wells and test borings not in the U.S. Geological Survey Ground Water Site Inventory data base

1b. Location of wells and test borings at the Swope Oil Superfund Site


DELAWARE
RIVER
PHILADELPHIA CO
BURLINGTON CO
CAMDEN CO
PENNSAUKEN
PALMYRA
Tidal Flat
Drive-in Theater
Eightmile Point
Charles Street Sch
Morgan Cem
Parry
Cem
Jordantown
Meadowbrook
Bon Air
Iron Rock
North
Playground
Townshp Sch
Pennsauken Jr High Sch
Golf Course
Wrightsville
RUDDEROW AVE
SORREL HORSE
FAIRFAX RD
WALNUT AVE
AVENUE
ADAMS RD
PIKE
BLVD
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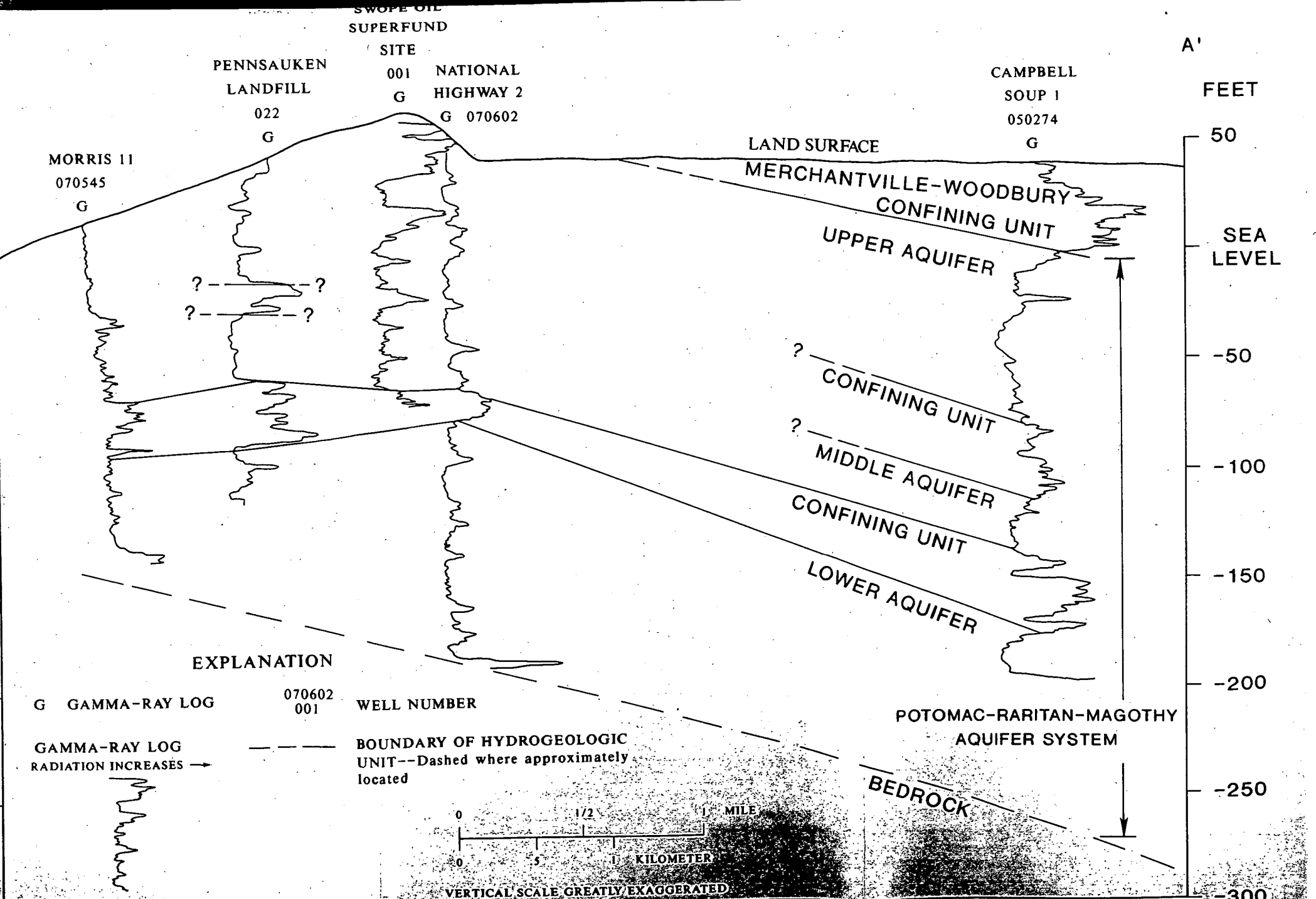

1d. Hydrogeologic section A-A'. (Line